



# **Zero Energy Buildings:** **Smoke?**



# **Mirrors?**

# **or What?**



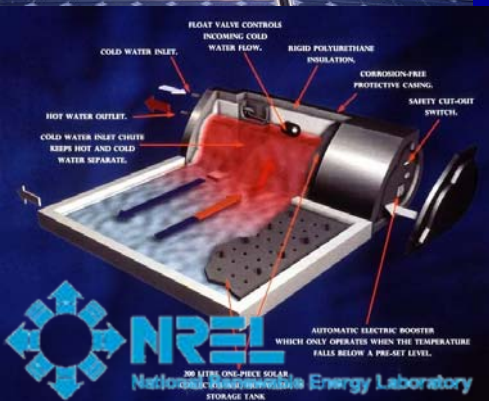
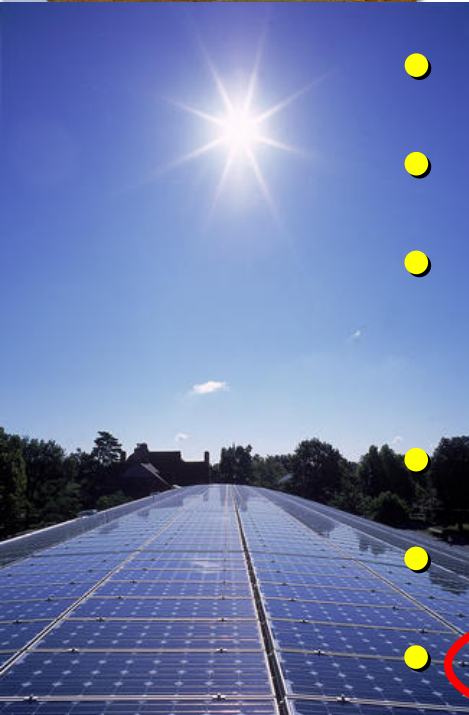
**Ron Judkoff**

**Principal Program Manager Buildings RD&D  
National Renewable Energy Laboratory**



# NREL Buildings R&D BA & CBI

- Measurement and simulation
- Systems Integration
- Ultra energy efficient Design
  - Zero Energy Buildings
- Passive/Active Solar, & BIPV
- Advanced HVAC systems
- Energy Optimization software







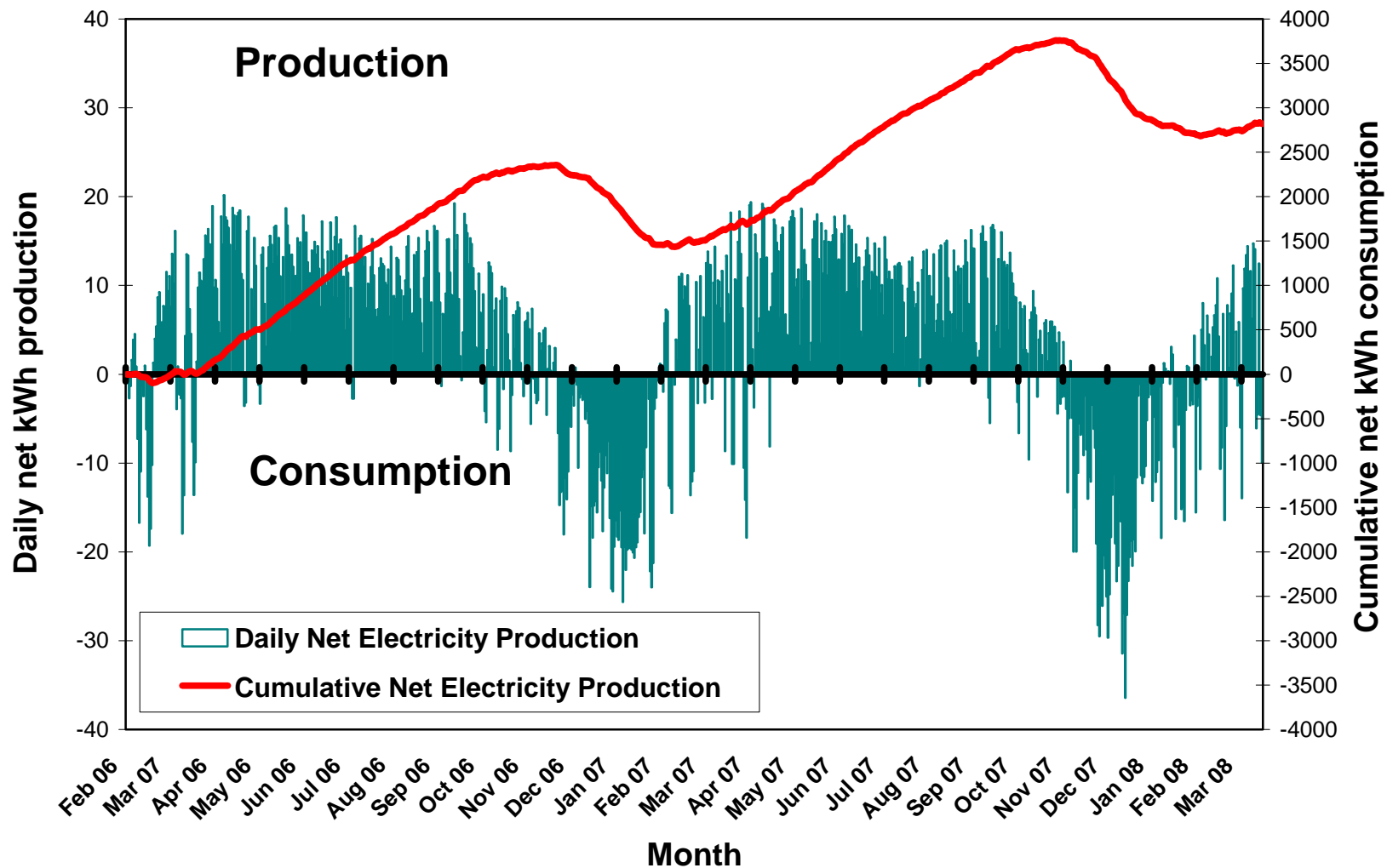
# NREL Zero Net "Site Energy" Habitat House

- Walls: R40
- Roof: R60
- Passive
- SDHW
- PV: 4 kW
- Heat Recovery

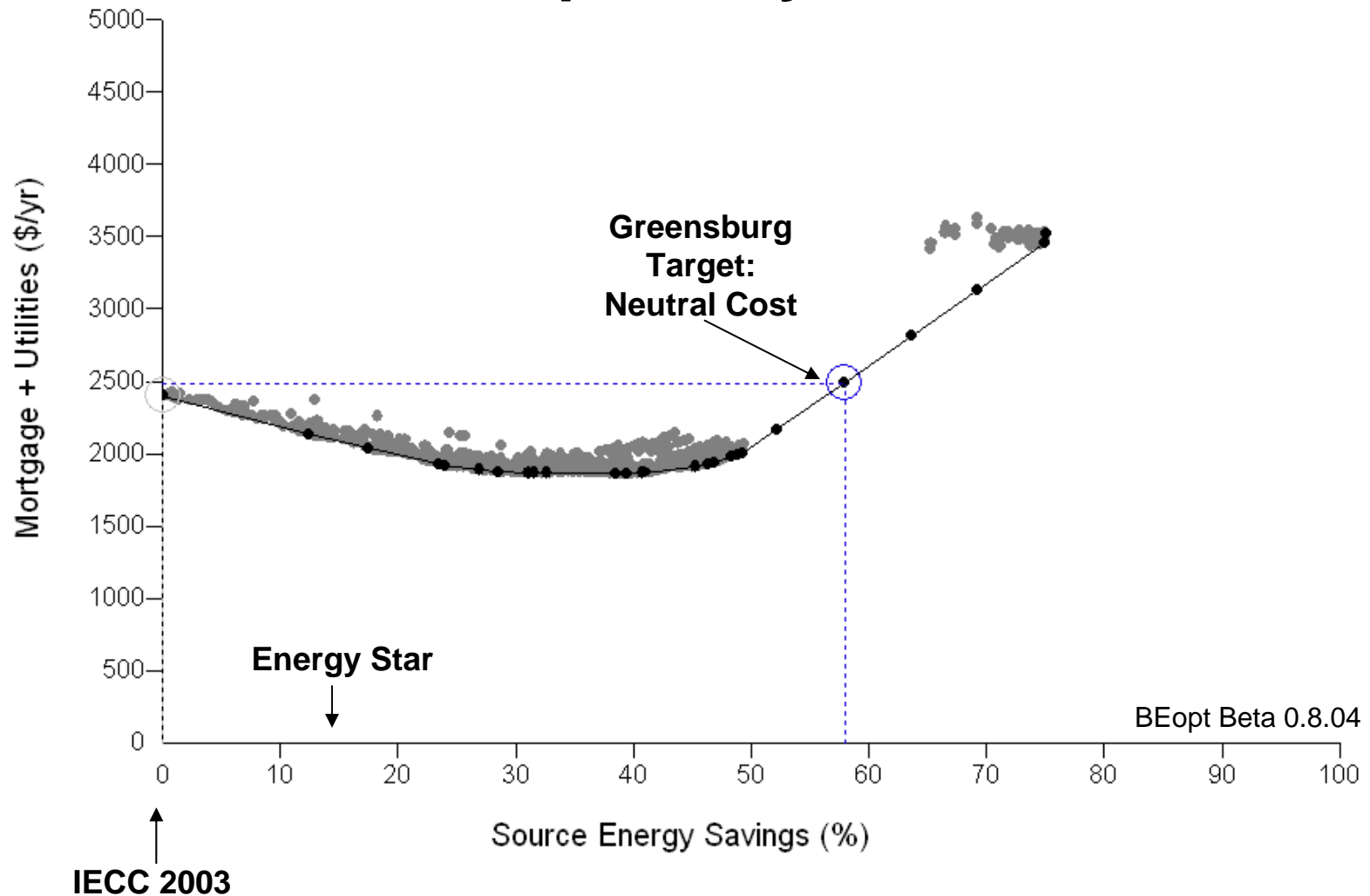


# NREL/Habitat ZEH

## Daily and Cumulative Net Electricity Production



# Neutral Cost Point: Greensburg BEopt Analysis



(2000 ft<sup>2</sup>, 2-story, 16% window to floor area ratio, unconditioned basement)

# Example: Greensburg Neutral Cost Package<sup>1</sup>

- R22 wall assembly (2x6 + R-19 batts+ foam sheathing)
- R50 ceiling assembly
- R10 basement
- .0001 SLA (2 ACH<sub>50</sub>): Approx = .12 nACH
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Gas tankless hot water, EF 0.8+
- Tight ducts (Mastic, 5% Leakage), in conditioned space
- Energy Star Appliances
- 1.5 kW<sub>DC</sub> PV System
- BA QA (moisture control, air quality, etc.)

Estimated cost increase relative to standard home<sup>2,3</sup>: +\$10.00-\$13.00/ft<sup>2</sup>

## Notes:

1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs will depend on current builder practice

# Estimated Annual Costs: Neutral Cost Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice	\$26,000
Annual Amortized Cost of Energy features (7%, 30Year mortgage <sup>1</sup> )	\$1386
Annual Utility Bill Savings	\$1386
<b>Net Annual Costs</b>	<b>\$0</b>

(2000 ft<sup>2</sup>, 2-story, 16% window to floor area ratio), unconditioned basement

<sup>1</sup> Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.



BigHorn



Cambria



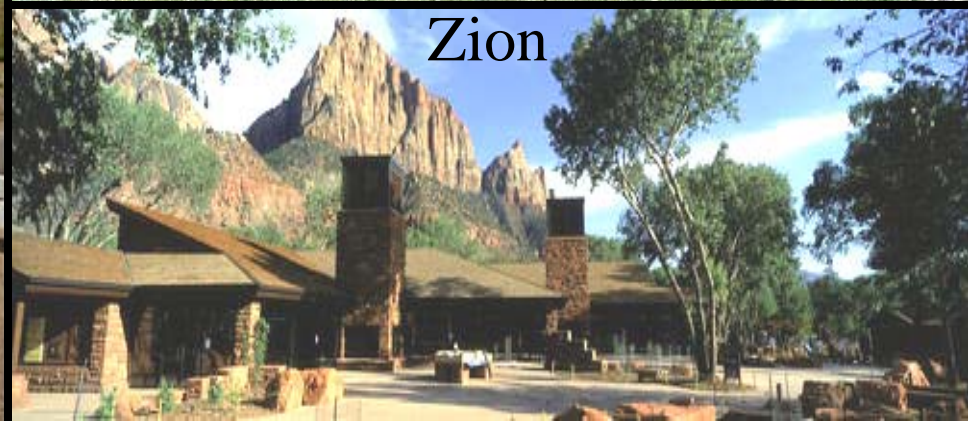
Oberlin



Chesapeake



Zion





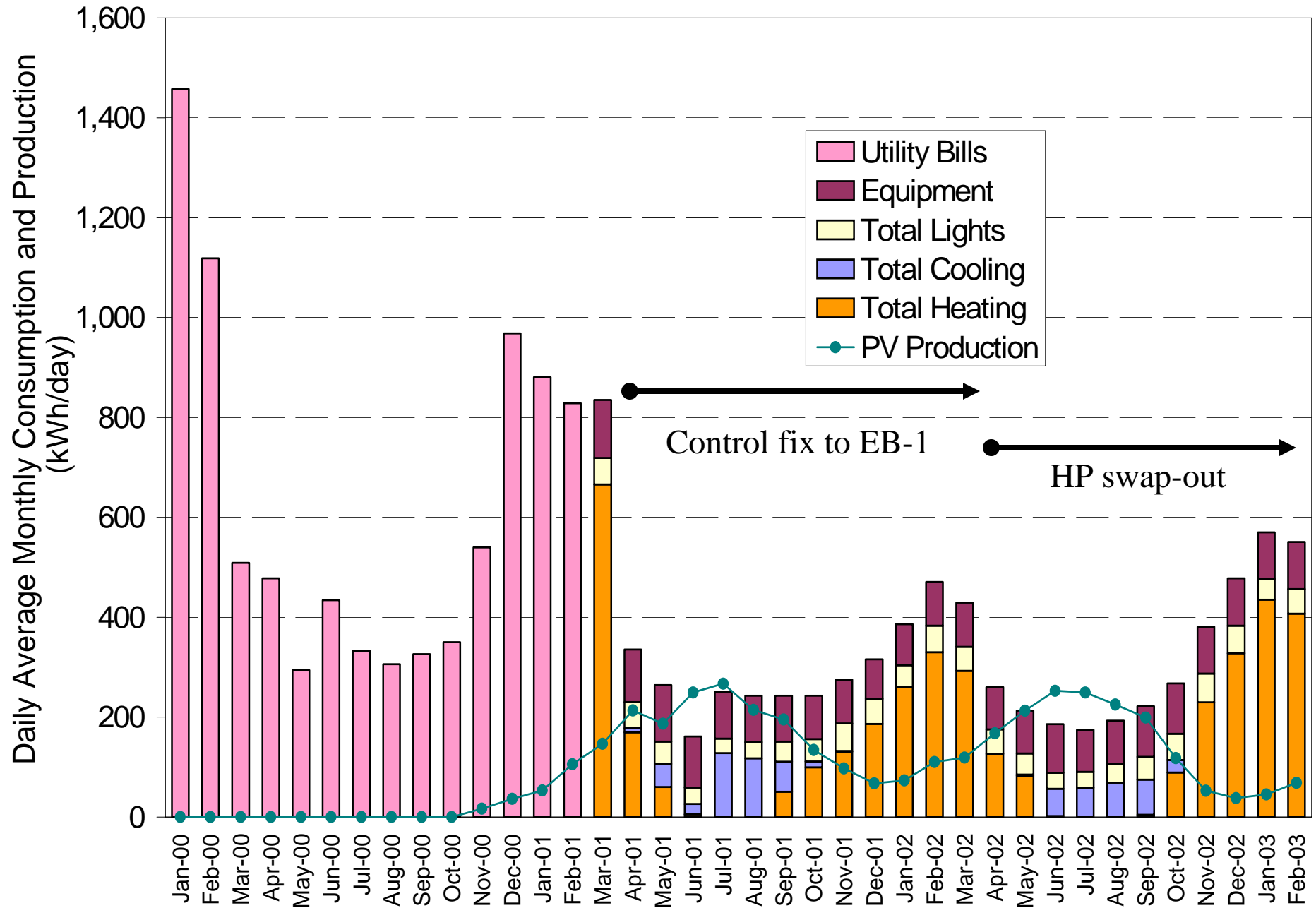
# On the Path to Commercial ZEBs

## Oberlin Lewis Center for Environmental Studies



- 14,000 ft<sup>2</sup> Classroom and Offices
- 60 kW PV
- Daylighting
- Natural Ventilation
- Ground Source Heat Pump

# Oberlin Before & After Fixes



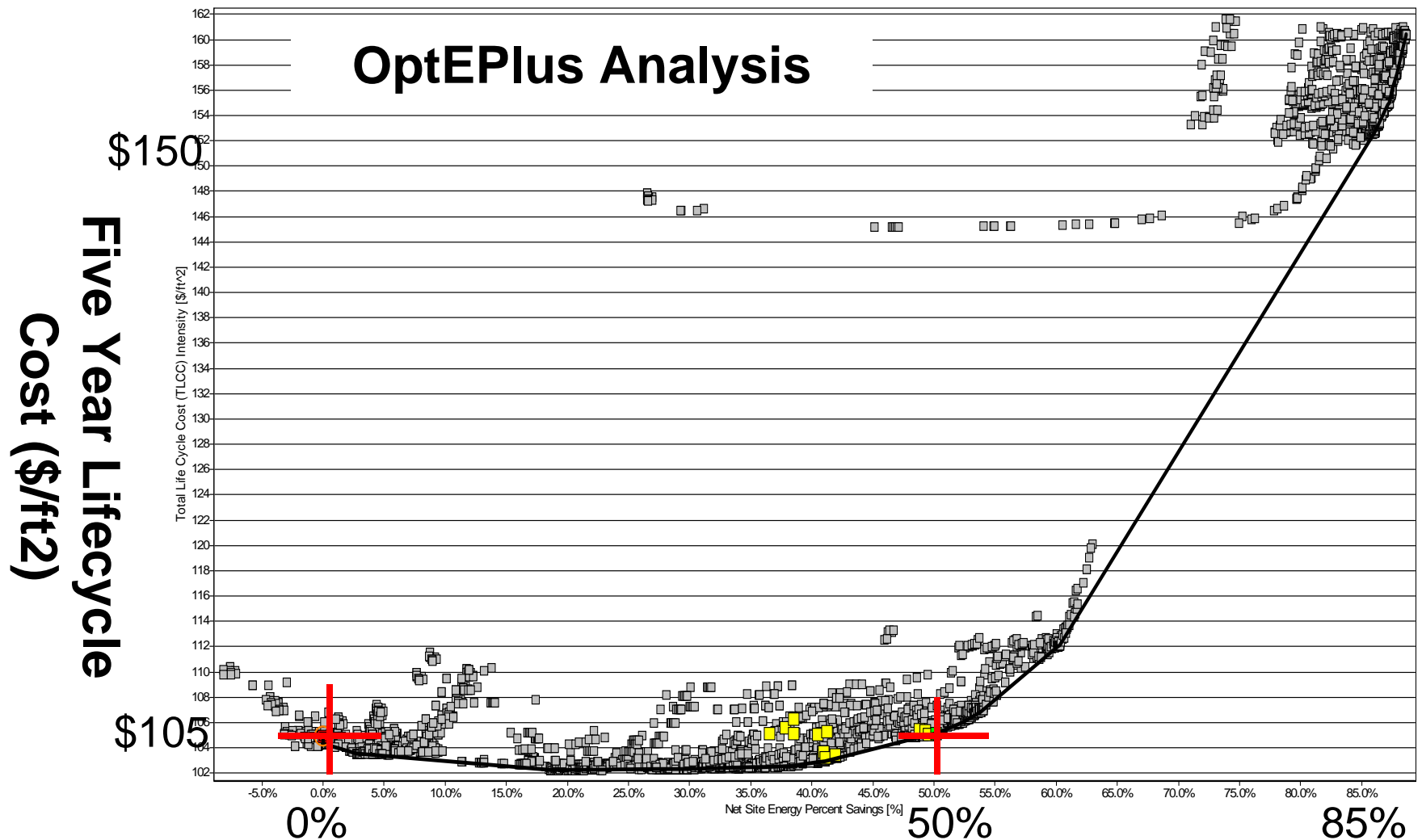




Oberlin PV Carport



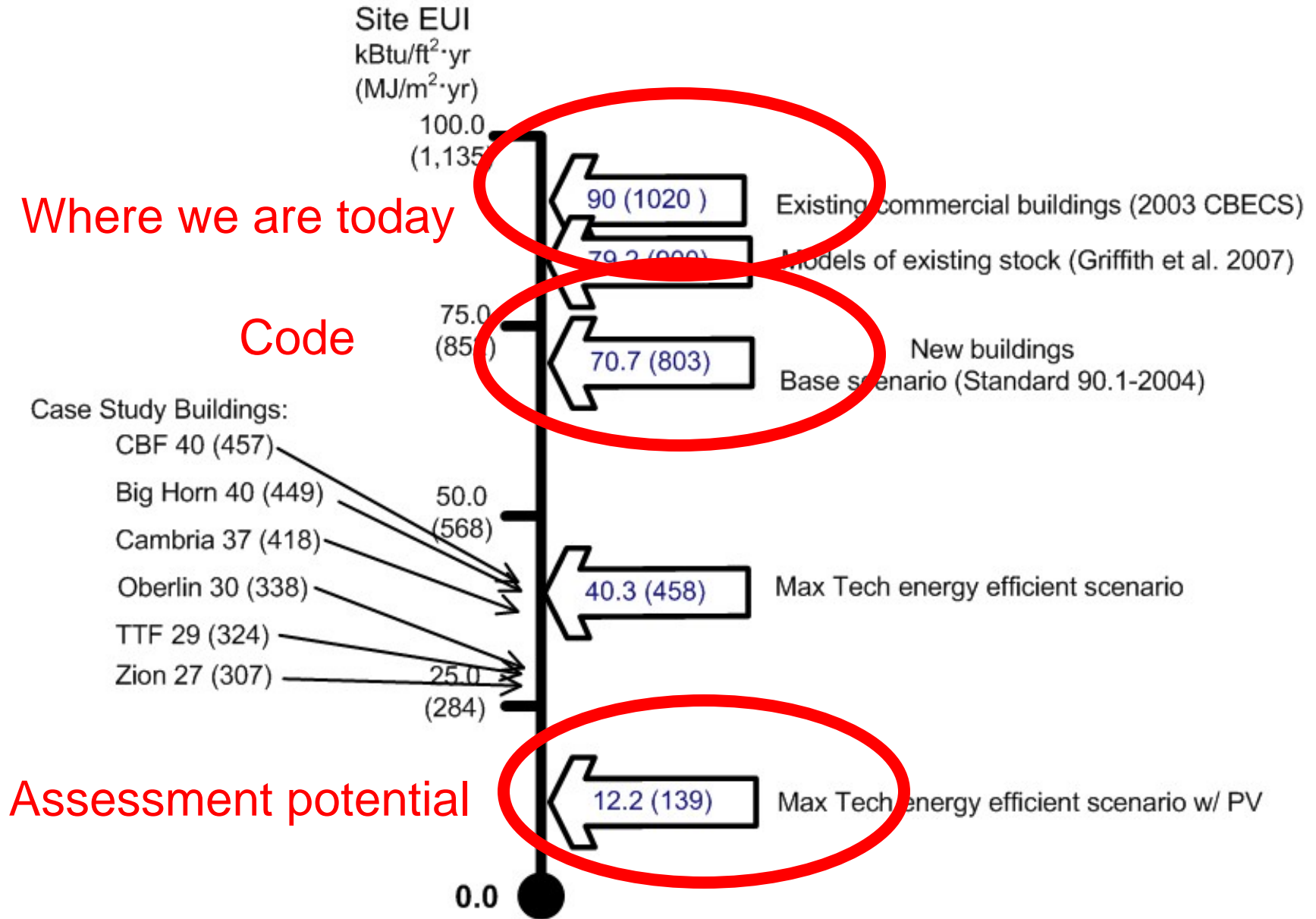
# Mid Size Retail Box, Boulder, CO

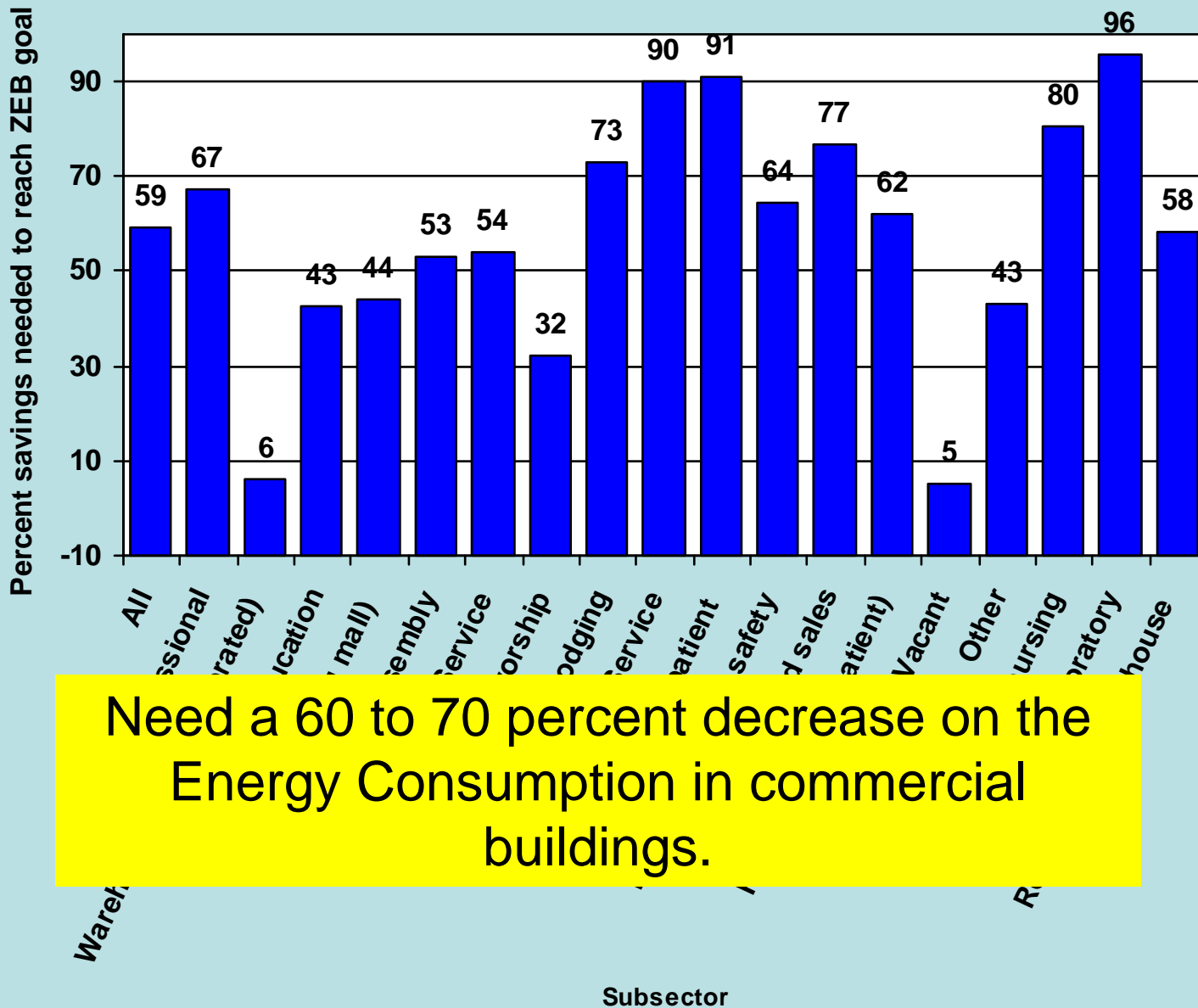


ASHRAE  
90.1-2004

**Site Energy Savings**





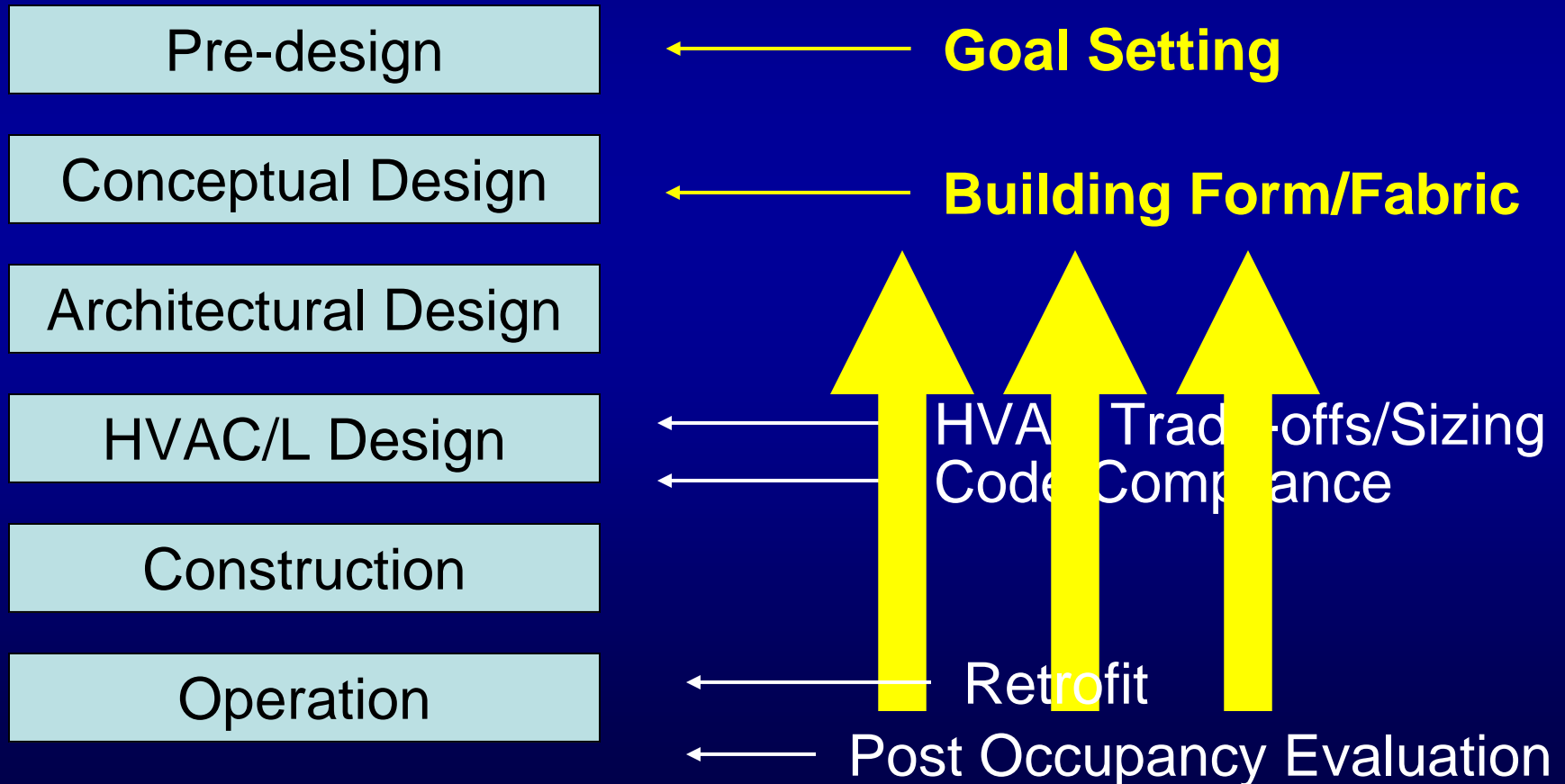


Need a 60 to 70 percent decrease on the Energy Consumption in commercial buildings.

Figure 4-17 Percent savings from efficiency needed to reach ZEB



# Stages of Design Process Using Simulation



# How to Achieve ZEB...

1. Envelope and Orientation to Reduce Loads
    - Well Insulated roofs, walls, floors, windows (with shading)
  2. Envelope and Orientation to Meet Loads
    - Daylighting
    - Passive Solar Heating, Trombe walls
    - Natural Ventilation
    - Cool Towers
  3. Lighting design to match daylighting
  4. Plug loads
    - Design vs. owner loads
  5. Climate specific HVAC designed for the remaining loads
  6. Commissioning (making sure the building works)
  7. Metering and evaluation
  8. Make it Simple
- 
9. Site Specific Renewable generation within footprint, site, off-site
  10. Small amounts of RECs

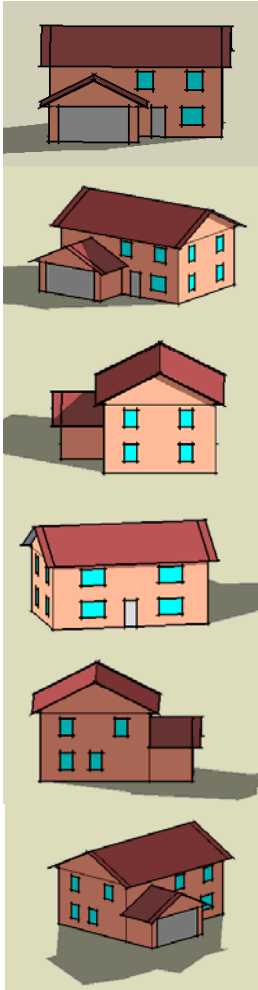
# **Path Forward: R&D Needs: Improve Simulation Models**

- **Complex & Innovative Systems & Controls**
  - Evaporative Cooling, Desiccant Systems, Innovative Storage Systems, Natural Ventilation Integration, Heat Pump Systems
- **Better Moisture Models**
- **Better Ground Coupling Models**
- **Optimization for Existing Buildings**
  - Calibration Methods
- **Dedicated Empirical Validation Facilities**
- **Multi-Building/Community Models & Optimization**

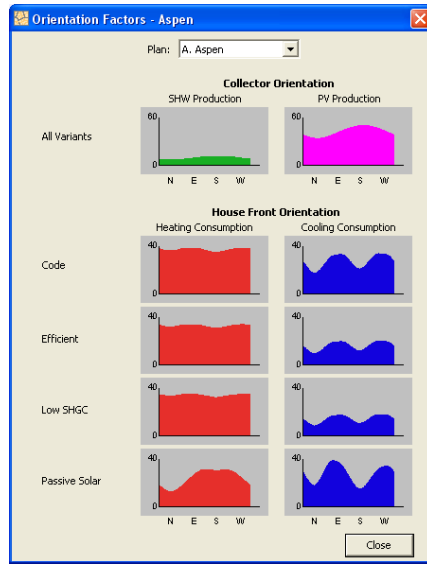


## Pre - Simulations

### Inputs



### Outputs



X

## SEAT

### Inputs

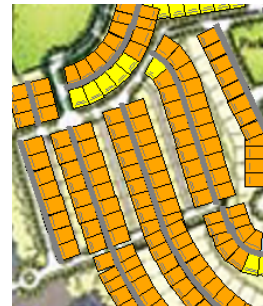
Variables	Design
1. Code	<input type="checkbox"/>
2. Efficient	<input checked="" type="checkbox"/>
3. Low SHGC	<input checked="" type="checkbox"/>
4. Passive Solar	<input checked="" type="checkbox"/>

PV	
Front	<input type="checkbox"/>
Back	<input checked="" type="checkbox"/>
Left	<input type="checkbox"/>
Right	<input type="checkbox"/>
Min Output (%)	90

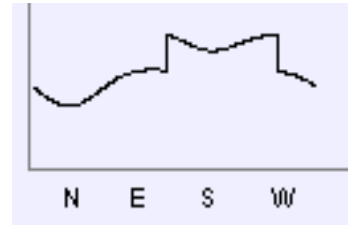
SHW	
Front	<input type="checkbox"/>
Back	<input checked="" type="checkbox"/>
Left	<input type="checkbox"/>
Right	<input type="checkbox"/>
Min Output (%)	90



### Outputs

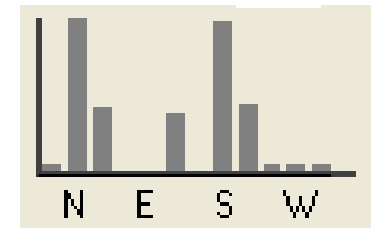
#### Energy

$$[ \text{Htg} + \text{Clg}_{\text{opt}} - \text{SWH}_{\text{opt}} - \text{PV}_{\text{opt}} ]_{\text{orient}}$$



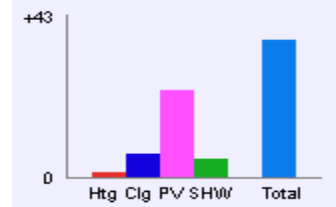
X

#### # Lots

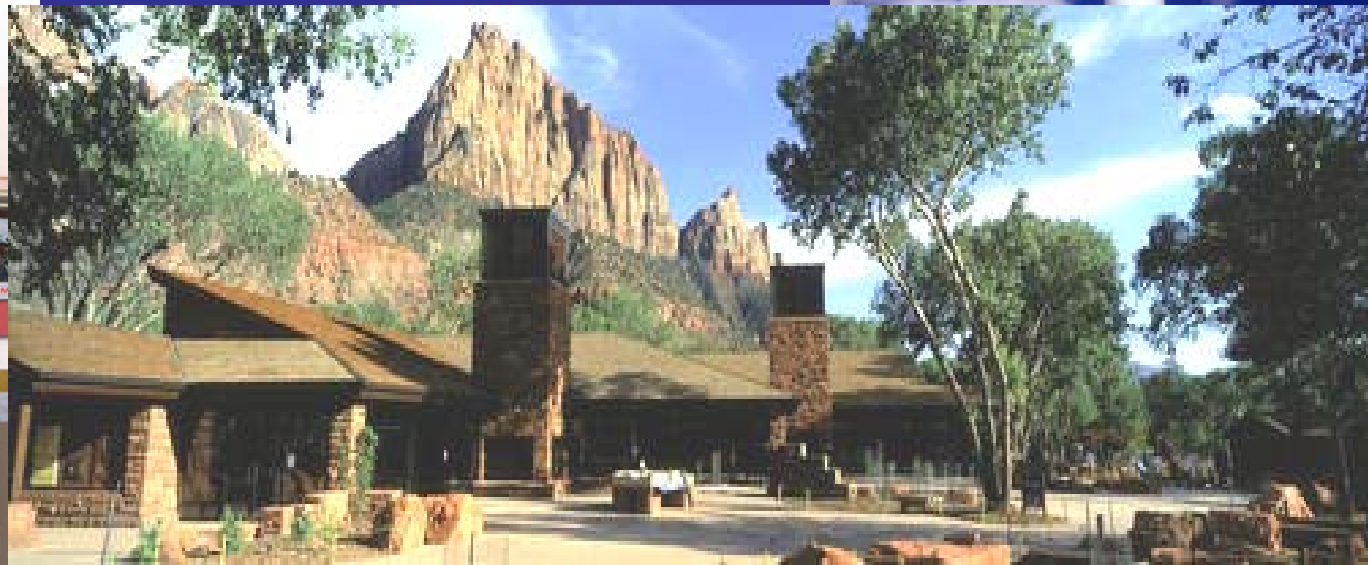


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#### TDV Savings (%)



**SEAT (Subdivision Energy Analysis Tool)**



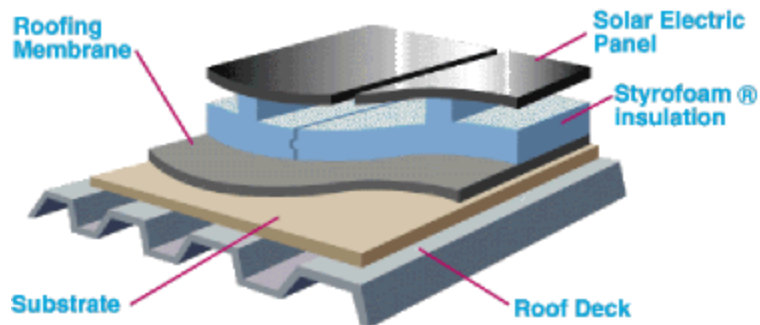
# BIPV Product Examples



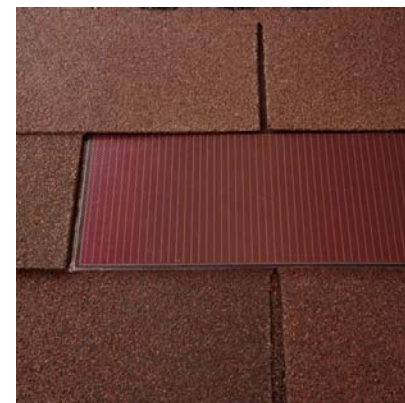
Flexible roof-top PV shingles



Building-integrated PV metal roofing modules



PowerGuard® system



Light, flexible PV roofing shingle for direct rooftop mounting



PV roofing shingles